World Academy of Science, Engineering and Technology
International Journal of Energy and Power Engineering
Vol:18, No:07, 2024

Towards Dynamic Estimation of Residential Building Energy Consumption in Germany: Leveraging Machine Learning and Public Data from England and Wales

Authors : Philipp Sommer, Amgad Agoub

Abstract : The construction sector significantly impacts global CO_2 emissions, particularly through the energy usage of residential buildings. To address this, various governments, including Germany's, are focusing on reducing emissions via sustainable refurbishment initiatives. This study examines the application of machine learning (ML) to estimate energy demands dynamically in residential buildings and enhance the potential for large-scale sustainable refurbishment. A major challenge in Germany is the lack of extensive publicly labeled datasets for energy performance, as energy performance certificates, which provide critical data on building-specific energy requirements and consumption, are not available for all buildings or require on-site inspections. Conversely, England and other countries in the European Union (EU) have rich public datasets, providing a viable alternative for analysis. This research adapts insights from these English datasets to the German context by developing a comprehensive data schema and calibration dataset capable of predicting building energy demand effectively. The study proposes a minimal feature set, determined through feature importance analysis, to optimize the ML model. Findings indicate that ML significantly improves the scalability and accuracy of energy demand forecasts, supporting more effective emissions reduction strategies in the construction industry. Integrating energy performance certificates into municipal heat planning in Germany highlights the transformative impact of data-driven approaches on environmental sustainability. The goal is to identify and utilize key features from open data sources that significantly influence energy demand, creating an efficient forecasting model. Using Extreme Gradient Boosting (XGB) and data from energy performance certificates, effective features such as building type, year of construction, living space, insulation level, and building materials were incorporated. These were supplemented by data derived from descriptions of roofs, walls, windows, and floors, integrated into three datasets. The emphasis was on features accessible via remote sensing, which, along with other correlated characteristics, greatly improved the model's accuracy. The model was further validated using SHapley Additive exPlanations (SHAP) values and aggregated feature importance, which quantified the effects of individual features on the predictions. The refined model using remote sensing data showed a coefficient of determination (R^2) of 0.64 and a mean absolute error (MAE) of 4.12, indicating predictions based on efficiency class 1-100 (G-A) may deviate by 4.12 points. This R^2 increased to 0.84 with the inclusion of more samples, with wall type emerging as the most predictive feature. After optimizing and incorporating related features like estimated primary energy consumption, the R^2 score for the training and test set reached 0.94, demonstrating good generalization. The study concludes that ML models significantly improve prediction accuracy over traditional methods, illustrating the potential of ML in enhancing energy efficiency analysis and planning. This supports better decision-making for energy optimization and highlights the benefits of developing and refining data schemas using open data to bolster sustainability in the building sector. The study underscores the importance of supporting open data initiatives to collect similar features and support the creation of comparable models in Germany, enhancing the outlook for environmental sustainability.

Keywords : machine learning, remote sensing, residential building, energy performance certificates, data-driven, heat planning
Conference Title : ICHTE 2024 : International Conference on Heat and Thermal Energy
Conference Location : Santorini, Greece
Conference Dates : July 11-12, 2024

Open Science Index, Energy and Power Engineering Vol:18, No:07, 2024 publications.waset.org/abstracts/185882.pdf